

1st A1 > TITLE

Device in a system operating with CAN-protocol and in a control and/or supervision system

5 TECHNICAL FIELD

The present invention relates to a device in a machine-control system and/or process-supervision system operating with the CAN-protocol according to standard ISO 11898. CAN-systems of this type comprise modules 10 which are intercommunicable via a digital serial communication and in which a control and/or supervisory function can be realised from a first module or from a unit, which is communicable with the CAN-system, belonging to one or more second module(s). The present invention is a single-day application made together with Swedish patent application "Device in a control and/or supervision system" submitted by the same applicant and the same inventor.

20 The present invention relates to a device in a machine-control system or process-control system. The said system has in the present case been referred to as a CAN-system, since the systems in question are required to use the signal protocol according to CAN (Controller Area Network, corresponding to standard ISO 11898). The invention in this case relates to those types of CAN- 25 system comprising modules which are connectable via a digital serial communication and in which a function in a first module is intended to be able to be observed, stimulated or registered at a location for the placement of the first module. Reference is also made to Swedish 30 patent application "Device in a system operating with CAN-protocol", which was submitted on the same day by the same applicant and inventor.

TECHNICAL ASPECT

35 It is previously known to be able to control machinery and equipment at control desks which are

connected via fixed connections or wireless connections. These proposals make use of the general control and supervision principles. With reference to control desk arrangements proposed with CAN-protocol, the arrangements 5 in question are primarily those with wire connections. Reference is also made to US 5,392,454.

With machine-control and process-control systems of this category, it is previously known that it is necessary to supervise the aggregates served by the 10 modules such that in fault-searching, system design, etc., it is possible to establish whether the equipment controlled by a particular module is behaving as expected. It can be stated in this context that it may be necessary to monitor the functions at valves, thermometers, etc., so that in certain functional states it can 15 be seen or registered whether the components in question are actually performing their expected function. It is also known to utilise machine-control systems and process-control systems in which the equipment parts are 20 connected via relatively long digital serial communications. The connection can also be established at locations and sites where accessibility is limited.

ACCOUNT OF THE INVENTION

TECHNICAL PROBLEM

25 In the radio-controlling of machines operating with CAN-protocol, problems arise from the fact that the protocol calls for arbitration and confirmation functions which are extremely time-critical. In order to ensure that the modules do not misinterpret a particular message 30 in question, in certain cases the receipt of a one over the connection must result, for example, in a zero being immediately presented to prevent disturbances occurring within the system. This calls for sending and receiving to be effected simultaneously by one and the same module, 35 which, in turn, calls for a full duplex connection and time synchronisation between the sending and receiving channel in each module and predetermined maximum wave propagation time within the system. This is difficult to

achieve in a radio system when such a system is often chosen to enable the distance between the modules within a system which are connected by radio link to be easily varied. Radiocommunication is therefore less suitable for 5 systems using the CAN-protocol. The object of the present invention is to solve these problems.

In certain contexts, it is vital to be able to make use of repetition functions linked to machines or machinery stocks operating with CAN-protocol. At places 10 which are difficult to survey or difficult to access, there is a need to build up an existing CAN-system and introduce a repetition function over difficult stretches or to create on a temporary or longer term basis two 15 separately working CAN-systems instead of one. In this context, there is a need to be able to facilitate system developments and system applications. The object of the invention is to solve these problems also.

There is also a need to achieve effective coordination of machine-controls in machinery stocks, 20 e.g. in weaving sheds in which weaving machines have hitherto been controlled individually and provided with their own man-machine interface such as control desks. There is a wish to be able to introduce CAN-protocol into the control of machines of this category, this having 25 been hindered by the above-specified problems. The object of the present invention is to solve these problems also and it is proposed, in respect of this category of machinery-stock control, that the controls be effected via radiocommunication from and to a common man-machine 30 interface, such as a control unit or control desk. The control equipment is thereby simplified and a coordinated, effective control is able to be established in terms of service and production via or in the machinery stock.

35 Radiocommunication is often utilised between an operator's control unit and the control system of the machine which he controls. Examples of such systems are radio-controlled airplanes, radio-controlled contracting machinery, radio-controlled hoisting cranes, etc. of

various types. One problem is here to set up a radio channel which is exclusively between control unit and machine, such that the connection is not disturbed by other operator/machine connections. The object of the 5 present invention is to solve this problem also.

The invention also allows reduced susceptibility to theft and offers high security within the system per se.

There is a great need to be able to carry out 10 fault searches and tests on modules which are situated at a distance apart and in which a functional effect upon a first module is wanted to be able to be followed at a second module, and vice versa. For instance, there is a desire in certain situations to initiate controls at a 15 master in the CAN-system in order to obtain manifestations at one or more slave modules. There is here a need to see whether the function is being correctly performed by the components or aggregates controlled by the module in question.

20 There is also a need to be able to stimulate a component or aggregate at a module and to discover what repercussions this has.

25 There is also a need to be able to carry out registration operations in a fault-searching and testing context for a certain period, as well as to acquire direct visual and signal information at the site for the module subjected to testing or fault-searching.

30 The above must be practicable even if the modules are far apart and hidden from each other. Preferably, the above will be able to be effected via an already existing switching function, i.e. connections and disconnections do not need to be made in each separate case/in respect of each module.

35 The invention aims to solve the whole or parts of the above problems.

THE SOLUTION

What primarily can be considered to be characteristic of a device according to the invention is that it

comprises two or more communication parts which form part of the CAN-system, respectively between the CAN-system and the unit mentioned in the introduction, and which are communicable via one or more wireless connections, that

5 when a transmission is made from a first communication part to a second communication part, the parts operate with a signal protocol which takes no account of arbitration and/or confirmation function(s) found in the CAN-system. A particular receiving communication part

10 executes or assists in the conversion of the said signal protocol to the signal protocol of the CAN-system.

In one embodiment, the communication parts can be coupled to the CAN-system, which in the non-connected or non-activated state of the communication parts forms a unitary system and which in the connected or activated state of the communication parts forms two CAN-systems which operate separately relative to each other.

A particular pair of communication parts can in this case operate with a protocol which is distinct from the CAN-protocol and is better suited for radiocommunication, e.g. Aloha, Ethernet, the "GPSP" WaveRaider protocol from GEC Plessey in England, etc. In one embodiment, the invention is utilised in respect of a machinery stock. As an example of a machinery stock can be cited weaving machines which are installed in one or more weaving sheds and are respectively allocated one or more modules. In this case, the unit can comprise a service unit common to a number of weaving machines, preferably the majority or all of the total number of weaving machines. This service unit can comprise or contain a personal computer (PC).

In the case of weaving machines in a weaving shed, one or more modules assigned to a weaving machine are connected to a service function in the weaving shed. This service function can consist of beam-changing, bobbin-changing, etc. Service staff receive information in parallel with a service machine which is appropriately connected to the particular weaving machine. Function information can therefore appear both on the unit and in

control apparatus belonging to the service machine, the function measure or instruction in question being able to be prepared simultaneously or in perfect coordination between the service machine and the staff involved. An effective synthesis is obtained for production and service measures which are necessary to the weaving machines in order to maintain effective production. The machines can be coupled together in a control network in which a particular machine has its own unique code and control system in order to prevent disturbances between the machines. The frequencies are preferably chosen within the broad-band range, i.e. 1 GHz or above, preferably the open ISM-band, but IR-frequencies and ultrasound frequencies can also be used. The latter particularly in respect of acoustic communication in an underwater environment.

The device according to the invention also relates to a system of mutually separate units which are intercommunicable by means of radiocommunications, these being able to be set up such that message channels can be realised between two or more of the said units. The radio communications operate here with an identification system in which a key allocation can be realised, which in a particular connection instance enables messages to be transferred between selected units only. The particular unit is further designed with a CAN-system (Controller Area Network), in which activations, control operations, functions, stimulations, readings, etc. in modules making up the unit are intercommunicable via a digital serial connection. The latter device is principally characterised by the fact that in each connection instance the key allocation between the units is based upon an identity/identities which, during a connection process for the connection in question, are acquired from a module in the CAN-system concerned and/or from a master system or master control centre. Further features of the devices in question can be derived from the following patent claims.

What primarily can be considered to be character-

istic of a device according to the invention, comprising the module mentioned in the introduction, is that a radiocommunication apparatus is arranged for connection with a part belonging to a second module in the system
5 for the establishment of a radiocommunication channel between the location for the placement of the first module and a location for the placement of the second module. At the location for the placement of the first module, radiocommunication equipment can be activated for
10 initiation via a radio channel and the said part of the radiocommunication equipment by activation of a signal in the second module. This signal activation causes the first module to perform its particular control and/or supervisory function which then becomes able to be
15 observed or registered in place of the first module.

In one embodiment, the CAN-system forms part of a machine-control system and/or process-control system in which a first signal exchange according to the CAN-protocol obtains between involved modules within the system for the control operation and the performance of the process. A first activation of the radiocommunication equipment at the first location hereupon gives rise to a second activation of circuits in the second module. This second activation induces the said signal activation in
25 the second module.

In a further embodiment, the signal activation caused by the second activation gives rise to message initiation in the second module, which prepares to dispatch a message via the module's communication circuit, over the connection to the first module. The second module is hereupon able to transmit the thus generated message, with a predetermined order of priority, in the ordinary message or signal exchange between the modules.
30 In one embodiment, the second module can cause interruption to the ordinary message or signal exchange in the CAN-system. That signal activation in the second module which is herein initiated by the second activation takes
35 over the CAN-system for the generation and sending of one or more test messages via the communication circuit and

the connection to the first module.

When its signal is activated on the basis of the second activation in the second module, the second module can imitate a control or supervisory function which can normally be found in the machine and/or process-control system. Alternatively, or as a supplement thereto, a control and/or supervisory function which is especially cut out for the testing function is generated.

The radiocommunication equipment preferably operates two-way (half or full duplex). This makes it possible for a stimulation of control or supervisory component(s) or equipment at the first module to produce a feedback to the second module, via the connection to the second module. The latter generates a stimulation-responding information signal, which is fed back to the radio equipment part situated at the first module. Information which is transferred via the radiocommunication equipment can thereby be indicated or presented on or at the said radiocommunication equipment part at the first module.

In one embodiment, the radiocommunication equipment part at the first module is connected to the control and/or supervisory equipment served by the first module and/or directly to the module.

In one embodiment, the second module is arranged such that it is merely a so-called "gateway" between the radiocommunication of the first unit and the CAN-system, i.e. a message from the first module via radio to the second module is converted there to a CAN-message and transmitted on the bus, and vice versa.

Further characteristics derive from the following patent claims and the description. The device also therefore works in cases where the equipment in the first module is stimulated, for example, manually, which stimulation can be monitored at the control or information-supplying unit to ascertain whether there are faults in the equipment and/or the communications.

ADVANTAGES

- Radiocommunication between control units and machines in machinery stocks can be economically established even where the machines operate with CAN-protocol.
- 5 Repetition functions can be inserted into the CAN-system or the machine and/or process-control system, which means that connections can be established for even poorly accessible locations. Proven methods are in fact able to be used in connection with the radiocommunication control
- 10 operation, as regards control desks, frequency usage, security arrangements, coding, keys, etc.

The above makes it possible for testing and function-checking to be easily carried out on CAN-modules, using simulated control operations and stimulations which are introduced to second modules at a distance from the first modules. The checks can be executed even if the connecting line is long, e.g. 800 m, or the modules are hidden from one another. The stimulations can also be carried out on the visually supervised module or its equipment/components and the reactions to such stimulations can be obtained in a second direction within the CAN-system and recorded at the location for the first module(s).

DESCRIPTION OF THE FIGURES

- 25 A currently proposed embodiment of a device exhibiting the characteristics which are indicative of the invention shall be described below with simultaneous reference to the appended drawings, in which:
- Figure 1 shows radiocommunication between a unit and a CAN-system
- 30 Figure 2 shows how a CAN-system with repetition function can be divided into two CAN-systems.
- Figure 3 shows how a CAN-system can be arranged with a control unit which can work either directly connected to the CAN-bus and then utilise power from this system or via a radio channel and then be powered from a chargeable battery,
- 35 Figure 4 shows transmitting and receiving units via a

radio channel in a radiocommunication system, in which transmission takes place in a protocol distinct from the CAN-protocol and in which conversion to the CAN-protocol is realised on the receiver side, and

5 **Figure 5** shows a simple system in which an operator control module which works on the CAN-bus is easily modified from a wire-bound system to a radio-controlled system,

10 **Figure 6** shows a device which enables a CAN-message to be converted to a radio message, and vice versa,

15 **Figure 7** shows diagrammatically how protocol exchange takes place between the CAN-protocol and a radio protocol,

20 **Figure 8** shows a radiocommunication control system in respect of a machinery stock, e.g. in the form of weaving looms in a weaving shed,

25 **Figure 9** shows an arrangement for weaving machines in a weaving shed, in which information goes out to a service car in parallel with a control panel,

30 **Figure 10** shows a simple way of setting up a secure radiocommunication between a control member and a machine,

35 **Figure 11** shows a construction site with radio-controlled cranes and the establishment of a radio connection between these and a particular operator.

40 **Figure 12** represents a basic and block diagram of a CAN-system in which radiocommunication equipment parts are arranged at first and second modules in the system and in which the radiocommunication equipment has been connected to the second module in order to simulate stimulations therein, the effect of which upon the system can be monitored at the first module,

45 **Figure 13** shows in basic representation an antenna system for long transfer distances in

respect of equipment according to Figure 1.

- Figure 14 shows in block diagram form the structure of the module 4A according to Figure 1, and
5 Figure 15 shows in diagrammatic form the framework structure for digital signals which are used.

DETAILED EMBODIMENT

Figure 1 shows in basic representation a CAN-system 101A. By this is meant a machine-control and/or machine-supervision system. Alternatively, a process-control or process-supervision system can be obtained. The CAN-system is represented by a number of modules 102A, 103A, 104A, which serve their parts of the system in question. Also included are a control unit 105A and a radio module unit 106A connectable and connected to or forming part of the module 117A. The said modules can intercommunicate via a digital serial communication connection 107A. Figure 1 also shows a control desk function 108A comprising operating levers 109A and 110A and a personal computer 111A with possible display unit 112A. The unit 108A further comprises a module 113A, which can be synthesised with the modules on the bus via a radiocommunication system comprising a part 114A, and possibly also an adjustment unit 118A, in the unit 108A and the said radio module 106A. The radio module 106A and the part 114A can comprise transmitter and receiver, so that a two-way communication 115A, 116A is obtained. Communication takes place via established radio channels in the radiocommunication equipment and the latter operates preferably in the broad-band range, see above. The units 116A and 114A are provided with antennae 106aA and 114aA for the said communication facility. The modules 102A, 103A, 104A can in this case represent modules forming part of machines in a machinery stock in which a particular machine can operate with a number of modules. There is therefore a possibility of accomplishing controls from the unit 108A of the modules in question via the CAN-system. The said machines in the

said machinery stock can consist of weaving machines - described in greater detail below - installed in a weaving shed or of hoisting cranes within a construction area.

Figure 2 shows how a CAN-system 201A having a repetition function can be arranged to form two different CAN-systems 202A and 203A, the respective CAN-system here being equipped with radio modules, which can comprise transmitter and receiver in accordance with the equipment 106A, 117A according to Figure 1. The radio modules have been given the designation 204A and 205A respectively. The first CAN-system has the modules 206A, 207A, 208A, 209A and the second CAN-system has the modules 210A, 211A, 212A. Control functions can be performed via the modules 210A, 211A and 212A, via the pilot pins 213A, 214A and a personal computer 215A. If the radio modules 204A and 205A are uncoupled, then the CAN-buses 216A and 217A of the sub-systems can be joined together to form a common CAN-bus 218A in which the junction point has been denoted by A. In the case of separate coupling and jump coupling, the CAN-bus ends would naturally have to be correctly terminated and a power supply suitably arranged. Except for certain accruing delays to the message, the divided system will function as if it were coupled together without any changes in the system's software.

Figure 3 shows a further variant of a CAN-system 301A with modules 302A, 303A, 304A and 305A. Here too, radio modules 306A and 307A are utilised. The radio module 306A is tied to the CAN-system 301A, whilst the radio module 307A is assignable to a further CAN-system 308A, which can be connected in two alternative ways to the CAN-system 301. The one way is realised via a mechanical, galvanically separated or wireless connection 309A or via the radio modules 306A and 307A, which operate in a manner corresponding to the radio modules according to Figures 1 and 2. The CAN-system 308A is provided with three modules 310A, 311A and 312A for the inputting and receipt of information which is relevant to the system in

connection with control and/or supervision within the system. In this case, a battery system 313A is utilised to power the CAN-system 308A. When the system 308A is used at a distance from the system 301A and the radio connection is utilised, then power is supplied from the battery system 313A. When the systems are coupled together, then the battery system 313A is connected directly up to the power unit 315A of the CAN-system 301A via the inductive connection 314A and the battery system 10 is then able to charge its integral accumulators. The CAN-system 301A is coupled together with 308A by the connection 315A via an inductive coupling 316A. A system can thereby be coupled together or separately coupled to form two sub-systems without mechanical connectors having 15 pins and sockets, which often cause problems when exposed to wear and tear, corrosion and physical damage. In many cases, one and the same control unit can operate either conventionally "fixed" mounted and connected to the CAN-network or as a remote control unit. In the fixed position 20 the batteries are loaded. Whenever the unit is then wanted to be used as a remote control unit, it is simply disconnected from the system. In the fixed-coupled position, the radio units have agreed on all parameters which are required for wireless communication. An advantage 25 is also that the operating unit is able to be removed from the controlled unit and without a control unit the machine is difficult to steal.

Figure 4 shows a monitoring/control unit 401A, having one or more CPU's 402A, memories 403A, a CPU-integrated or free-standing CAN-Controller 404A (for example Intel 527A), a CAN-driver 405A (for example Philips 251A), communication adjustment circuits 406A, etc., diagrammatically illustrated, built for the CAN-protocol, which are connectable to a radio unit 408A and 35 also connectable to a CAN-connection 407A. The radio unit 408A comprises two communication parts, a radiocommunication part 409A having hardware and software, which enables a wireless communication to be set up between different radio units, and a part having hardware

and software, incorporating one or more CPU's 410A, memories 411A, communication adjustment circuits 412A, etc., diagrammatically illustrated, which allows communication with the unit 401A. Examples of such radio units 5 are WaveRider from GEC (GB) and examples of a CAN-unit are CANonBall and mini-CB from KVASER AB (SE). The radio part 408A and the CAN-part 401A have at least one CPU each and can intercommunicate via a serial or parallel interface 413A. The parts 401A and 408A can be built 10 together in a common casing 414A or each in its own casing, indicated by 415A, and can be connected by a connector 416A. An advantage of having the radio unit 408A and the CAN-unit 401A mounted each in its own casing is that the radio unit can be easily exchanged in the 15 event of a fault, replaced by a similar radio unit in order to satisfy national or regional radiocommunication regulations, or can alternatively operate with some other wireless communication based, for example, upon infra-red or visible light, ultrasound, etc. The CAN-part can in 20 this case be a standard unit with a parallel or serial output which allows connection to a unit equivalent to 408A. Each radio part has a unique identity, in the case of WaveRider an Ethernet address, and each CAN-unit has a unique identity, for example an EAN-number including a 25 serial number. Each unit which will be able to be controlled also has a unique identity, for example an EAN-number including a serial number.

The radio unit operates independently as regards 30 radiocommunication and has a network protocol for this. All radio units can intercommunicate within radio range on a common channel. Two or more radio units can be allocated or can themselves set up a channel which is exclusive to them. If further differentiation of the radio traffic is required, then two or more radio units 35 can establish an exclusive message channel within a channel by the messages being encoded with their own common key. Each station can be allocated a station name constituted, for example, by a binary code or an ASCII-file. By having two separate identification systems, one

for radiocommunication and one for CAN-communication, a very secure and flexible communication system can be established in which the system, apart from being a communication system, can also be used to distribute and check the authority of operators to operate machines.

Patent US 5,392,454 describes how two radio units can set up a common exclusive communication channel by first seeking contact with each other via another type of communication channel and by there exchanging information about each other's unique identity. By marking its messages with its identity during ordinary communication, a particular unit can thus filter out those messages which are intended for the unit in question. The fact that the identification of the message is based upon the identity of the radio unit represents a major drawback, firstly in respect of the exchange of radio units and secondly if multicast-type connections are wanted to be set up. The consequence of the solution proposed in patent US 5,392,454 is that the radio connection is tied between the transmitting and receiving radio unit and not between operator unit and machine or between machine sub-system and machine sub-system. The radio communication system can be regarded as the master machine-control system. The radiocommunication units are regarded as special units within the system.

In CAN-systems, for example those operating with CAN HLP (Higher Layer Protocol) "CAN Kingdom", it is usual firstly for each node or module in the system to have its own unique identity, which is based, for example, on an EAN-number and a serial number, and secondly for there to be a module or node constituting a system node in the machine system. The identity of this node can also be used as identity for the machine. In the present invention, the radiocommunication unit is regarded as a CAN-node of whichever type, equating, for example, to a valve unit or a joystick unit. The radiocommunication system is thus regarded as the subordinate machine-control system. When the system is started up or as soon as a radio unit is connected to the system,

the system node can detect this, for example by a method described in CAN Kingdom. Depending upon the situation, the system node can assign to the radio unit a general public network key or a unique key. A simple way of 5 constructing a unique key is to base this upon the identity of some node incorporated in the system, since all of them have a unique identity, inclusive of the system node itself. If, for some reason, a node other than the identity of the system node is chosen as basis 10 for the exclusive network key, then this is entirely possible, at least in systems based upon CAN Kingdom, with maintained system security, since the system node is aware of all integral nodes and no node can be exchanged and work within the system without the consent of the 15 system node. From a security viewpoint, it is vital that it is the system node of that sub-system which is critical to security within the total system which determines the network key and possibly also provides a jump plan or alternatively a dispersion code, depending upon whether 20 a jumping frequency or spread spectrum technique has been chosen. Examples of a suitable radio employing the latter technique is the "2.45 Spread Spectrum Transceiver" from CRL Instrumentation in England. For example, in a system comprising a hoisting crane and a remote control unit, it 25 is the system node in the hoisting crane which has to assign the common network key to a particular radio unit, not any of the radio units or the system node in the remote control unit. Alternatively, network keys can be distributed at a still higher level within the system. 30 For example, a unit which is common to a construction area can distribute network keys via a common channel to remote control units and cranes. The area-common unit then has complete information on all cranes and the identities of remote control units within the area. It is 35 vital that the radiocommunication units should be at a low level systematically within the machine system and hence fully exchangeable without security risk. The problems associated with radio transmission, such as, for example, jump plan, jumping frequency, dispersion code,

identification of radio transmitter and receiver, distribution of station identities, etc. can be solved wholly within the radio system range and the machine system constructor needs only to ensure an adequate network key distribution. A hierarchically structured machine system includes an organisation for the generation and distribution of network keys and an organised way of identifying individual modules and groups of modules. The radio system includes an organisation for the generation and distribution of communication channels and an organised identification of individuals and also possibly groups of radio stations. The fact that the machine system distributes the network keys and has scope to acquire and employ information on the identities of stations forming part of the radio system means that radiocommunication in a CAN-system can be used securely. The identity of the station in the radio network can be exchanged by the system node for the identity of the system node, in which case the system ceases to form part 20 of the original radio network.

Having CAN-modules whose only tasks are to constitute units for wireless communication, hereinafter referred to as WCANM, is a major advantage in CAN-systems. An example: We have two wireless units, WCANM1 and 25 WCANM2. In stage one we couple them together via the CAN-connection and they perform the start-up process and can subsequently intercommunicate in a secure manner. In a system which is traditionally constructed, then it is now possible to remove a unit, for example a control lever and monitoring unit, and replace this with a WCANM1. The removed module is now coupled together with WCANM2 and we have a wireless connection between the monitoring/control unit and the rest of the system. In its simplest form, WCANM1 will now receive all messages on the CAN-bus. As 30 and when a message is correctly received, it is repackaged into a WCANN-message [sic] and sent to WCANM2, which unpacks the message and converts it into a CAN-message and sends it to the monitoring/control module. This module cannot distinguish between a message which

has undergone these conversions and a message which has arrived directly on the CAN-bus, if the CAN-Identifier is the same. When the control/monitoring module sends a message, the reverse takes place. WCANM2 receives the 5 message, repackages it, transmits it to WCANM1, which repackages and sends out the message on the CAN-bus.

Figure 5 illustrates a process according to the above. A CAN-system comprises a CAN-bus 500A, to which the modules 501A, 502A, 503A, 504A and 505A are connected. The module 505A is a control module to which the control levers 508A and 509A are connected and with which the control command can be given to 501A and 502A or 503A and 504A respectively. By decoupling the module 505A from the CAN-bus 500A and instead connecting up the radio module 511A and connecting the radio module 510A to the CAN-bus instead of the module 505A, a wireless connection has been obtained between the control module and the CAN-bus. 10 15

Below and in Figure 6, a detailed account is given of how a CAN-message is converted into a radio message and vice versa. A message is created by the CPU 602 in module 601A and transferred to its CAN-Controller 603A for dispatch. Apart from data, the CPU sends information on the CAN-Identifier to which the data is to be coupled, on whether this identifier is of the standard or extended type, on the fact that it is a data message and not a so-called "remote request" and on the number of bytes which the data occupy in the data field. The CAN-Controller converts this information into a bit pattern according to the CAN-protocol, in which, inter alia, a CRC check code for the message is worked out, and transmits the bit pattern 701A on the CAN-bus 600A according to the rules of the CAN-protocol via the CAN-driver 604A. Once the CAN-Controller 607A of the WCANM-module 606A has correctly received the message, then information corresponding to the CPU in module 601A is downloaded to its CAN-Controller so as to be accessible to the CPU 608A of the WCANM-module. This reads the received information and packages it into a data format which is common to WCANM- 20 25 30 35

modules:

Bytes 0-3	CAN-Identifier
Byte 4	Data Length Code
Bytes 5-12	Data Field 20

5 Note here that a CAN-Identifier is only a bit pattern and that the arbitration characteristic associated with this part of a message according to the CAN-protocol is of no importance to the radio transmission and that the CRC-code and acknowledgement bit are not transferred. The data string 702A, in Figure 7, according to the above is transmitted to the CPU 610A of the radio unit 609A via a local serial or parallel bus 611A for sending. (The interface 611A can comprise eight leads for data, six leads for handshaking, three in each direction, and a feedback signal lead for initiating the radio at the start-up of the system). The CPU 610A then deposits the data string as data according to the protocol used by the radio units amongst themselves 703A. Here the data are treated as whichever data and the CPU 610A is not therefore required to have any information on the CAN-protocol. The radio message having been transmitted, the CPU in the radio unit of a receiving WCANM-module, following receipt according to the radio protocol, uses the local bus to transmit the received data string 704A to the CPU of its module's CAN-part. The CPU of the CAN-part then creates a CAN-message 705A in accordance with the format of the data string and presents this to its CAN-Controller for dispatch on the CAN-bus and the process continues in the customary CAN manner. The CAN-Controller calculates a new CRC check code and presents a one in the acknowledgement slot, since it is transmitter of a message which is new to this part of the system.

35 In CAN-systems constructed with CAN Higher Layer Protocol "CAN Kingdom", an application in a module is tied together with a CAN-Identifier via a so-called "Folder" to allow the data exchange between applications in different modules to be coupled together. If the CAN-system is constructed according to CAN Kingdom, the

Folder number can be used instead of the CAN-Identifier in the format of the data string 702A and the Data Length Code omitted:

5	Byte 0	Folder Number
	Byte 1 - n	Data n = 0 .. 8

Other necessary information derives from the particular "Folder Label" in accordance with the CAN Kingdom protocol. The length of the ether-borne message is thereby reduced. Furthermore, different CAN-Identifiers can be used for the very same message in the various sub-systems. This can be an advantage, since the priority of the message can then be adjusted to the conditions in the particular sub-system. In systems developed for radiocommunication, only messages necessary to a particular receiver are sent via radio and each sub-system has an internal flow of messages between its nodes.

In CAN-systems it often happens that modules are set to receive only certain messages. This is generally done by filtering out certain bit patterns in the arbitration field of the CAN-protocol, which in specification ISO 11898 is known as the Identifier Field. Since, from a CAN viewpoint, WCANM-modules can be quite ordinary CAN-modules, these also have the scope to filter out messages on the bus. If it is known which messages are to be received on both sides of the wireless communication, then WCANM1 and WCANM2 respectively can be set to filter out those messages which are to be received on the respective other side and thereby reduce the load on the wireless connection. Since there is no known method of satisfying the time demands which are placed upon the acknowledgement bit of the CAN-protocol via a wireless connection with a high bit speed, typically 125 kb/s to 1 Mb/s, over longer distances, typically from a few metres up to five hundred metres, the wireless communication is not bit-synchronous with the line-bound communication. Since the CAN-protocol is not followed in ether transmission, this can often be done faster and with different scheduling of the message transmissions. If

standard circuits for CAN are used, then it may be expedient to take the message as it appears in the normal reception buffer which is read by the CPU, i.e. with CAN ID field, control field and data field, but without start bit, stuff bits, CRC bits, etc., and to transmit this according to a protocol suitable for wireless communication. Another alternative is to receive from the CAN-bus entire bit streams and to buffer these as far as the acknowledgement bit. When this is read to zero on the CAN-bus, the packet is transmitted via the ether and, following receipt, the bit stream is transmitted on the CAN-bus on the reception side. From the acknowledgement bit onwards, the receiving WCANM-module itself creates remaining bits according to the CAN-protocol. If, during this period, the first WCANM-module reads an error frame after the acknowledgement bit during the remaining part of the CAN-message, then an error code is immediately transmitted to the receiving WCANM-module, which then sends out an error frame on its CAN-bus. This is an effective way of sending CAN-messages, since CAN's error controls are utilised (and therefore no error control is required in the ether protocol) and there are few bits needing to be transmitted. The problem remains however, when some bit is incorrectly received from the ether or, worse still, a CAN-error arises on the CAN-bus belonging to the receiving side. It can then be too late for the receiving WCANM-module to send an error message over the ether. The original message can already have been accepted on the sending side. This problem can be solved in the CAN Higher Layer Protocol.

A further way of compressing the message which can be utilised, especially when the ether communication is operating at high bit speed, is for the bits of the CAN-message on the sending side to be received up to the point where the CRC-code and the stuff bits are removed, since these are not involved in the working-out of the CRC-code by the CAN error protocol. This packet is transmitted via the ether and, if the CRC-code is correct on arrival, then a CAN-bus is recreated.

The communication between WOANM-modules [sic] can be of the full duplex or half duplex type. Full duplex offers the fastest transfer, since, if the receiver detects an error, it can immediately send back an error message to the transmitter. In the case of half duplex, the receiver would have to wait until the whole message is sent before a reply can be given. Radio networks are most commonly of the half duplex type. A typical sequence is as follows:

- | | | |
|----|-----------------------|--------------------|
| 10 | Transmitter | Receiver |
| | 1. Set up connection. | 2. Acknowledgement |
| | 3. Sends message | 4. Acknowledgement |

15 5. Disconnect the connection

A more effective procedure is to send short messages constantly to and fro between the transceivers. A CAN-message is always short in comparison to necessary information in a radio network protocol for the 2.4 GHz band (the ISM band), in the order of magnitude of 11 to 154 bits depending upon the way in which the information is packed in the radio protocol. It is therefore expedient for the CAN-information to be included in the "Establishment of connection" message and the acknowledgement message, thereby providing an effective use of the channel. The fact that a short message is "ping-ponged" in this way means that a system-supervising node in the CAN-system has the chance to have continuous information stating that the radio connection is intact and functioning. A broad-band communication further requires that the clock in a particular transceiver module shall in some way be synchronised with a real or virtual system clock. A constant exchange of short messages between stations in the system allows good precision to be maintained in the system's clocks, thereby enabling the creation of an effective broad-band protocol built on jumping frequency or bit-pattern synthesis and enabling the clock of the radio system also to be used as a system clock within the CAN-system.

An ever increasing number of modern weaving looms are constructed with a CAN-system. Each weaving loom has a display, a key set and very often also a memory card reader. These devices are utilised only when a person 5 operates them, i.e. for the vast majority of the time they are totally redundant items of equipment. It is usual for one person to have responsibility for twenty or so weaving machines. Often all weaving machines are connected to a network having a supervisory function and 10 the person in charge acquires information telling him which machine to go to in order to carry out some form of service. By connecting WCANM-modules to each weaving machine and a WCANM-module to a portable unit suitable for passing and taking information from a person, a so-called "Man Machine Interface (MMI)", for example a 15 portable personal computer, a number of advantages are attained. All displays, key sets and memory card readers can be removed. When the person stands at the machine, he connects his MMI to the CAN-network in the manner previously described. Since only one MMI is required per 20 person, this can be considerably more powerfully designed than if there were one to each machine. Data files which were previously transferred using memory cards can now be transmitted from the MMI. Fault analysis programs, 25 graphic presentation, tuning tool programs, etc. can be incorporated in the MMI and keyboards, mouse, etc. can be made user-friendly and upgraded more regularly than the machines. Communication with the person often draws on greater computer resources than the machine-control 30 function, so that the machine-control function can be made cheaper, more secure and more effective in that these functions are taken over by the MMI.

When the operator is not directly connected to a machine, he is connected to the wireless network. As soon 35 as a machine requires action on the part of the operator, the machine sends out a message on the wireless network. The operator brings up on his display a list of all weaving machines which have requested assistance and for what reason. If more than one machine has requested

assistance, the operator can choose the order in which he shall attend to the machines and he is also prepared for what has to be done so that he has suitable tools with him.

5 Figure 8 shows a diagrammatic representation of a device according to the above. Each weaving machine 808A, 802A, 803A, 804A, 805A, 806A and 807A is equipped with radio modules 801aA, 802aA, etc. and has in each case an internal CAN-control system which can communicate
10 with the radio module. The operator has a PC 808A to which a radio unit 808aA is connected. When the operator is supervising the plant, all radio units operate on the same channel and information can be exchanged between the PC and all weaving machines. When the operator is working
15 on a weaving machine, the PC and the weaving machine use an exclusive channel, direct communication with the weaving machine 801A being illustrated in the figure. A further advantage is that the wireless network can replace the currently wire-bound network for production
20 data to and from the machines and for supervision thereof.

The automation of a factory often incorporates various types of driverless trucks and similar equipment which also have an internal CAN-control system. These can
25 also be connected up to the wireless system. Figure 9 shows a diagrammatic representation of a small part of such a system with a weaving machine 902A, a driverless truck carrying a replacement beam 904A and an operator unit 903A. If, for example, a warp beam is to be replaced, then a message 901A reporting this can pass
30 from the weaving machine 902A both to the operator 903A and to the unit 904A transporting replacement beams. This, in turn, can send a message 905A to the operator about its status. When the operator arrives at the
35 machine, the driverless truck with the replacement beam is already there. In the event of further automatisation, the fixed machine interacts automatically with the moving machine and the operator is summoned only if the machines, for some reason, have failed in their task.

Figures 10a and 10b show an example of the above process. A monitoring/control unit 1001A equipped with a radio unit 1001R is connected via a CAN-bus 1002A to a machine 1003A equipped with a radio unit 1003R. The 5 system-supervising node 1004A of the machine detects that a monitoring/control unit 1001A is connected to the machine and asks the system node 1005A of the unit 1001A for the EAN and serial numbers of the monitoring/control unit and uses these to check whether the unit 1001A is of 10 the right type and whether the individual is authorised to control the machine 1003A. The method for carrying out such a check is, inter alia, described in CAN Higher Layer Protocol "CAN Kingdom". If another monitoring/control unit 1006A already has control over the 15 machine, the connected unit 1001A is denied further communication with the system in the machine 1003A. If no previous monitoring/control unit has control and type and possibly also the new individual is authorised to control the machine, then the machine transmits a unique station 20 name 1007A, for example the EAN-number, inclusive of serial number, of the unit 1001A. This station name is subsequently used jointly by the machine and the monitoring/control unit as identity for their communication channel. The CAN-connection 1002A is disconnected and 25 communication can be made via radio as shown in Figure 10b. Figure 10b has revealed that the radio units 1001R and 1003R have been exchanged for the compatible units 1011R and 1010R after communication has been established. This is totally feasible by virtue of the fact that a 30 particular system node 1005A and 1004A delivers the agreed channel code to the respective new radio units, once these have been connected to the respective CAN-network.

Figure 11 shows a more complex process. A company 35 has a number of cranes 1101A, 1102A, 1103A at a work site. All cranes have a unique identity, 1i, 2i, 3i and are each equipped with a radio unit 1r, 2r, 3r. Each crane operator 1104A, 1105A, 1106A has his own monitoring/control unit with radio. Each such monitoring/control

unit has a unique identity, 4i, 5i and 6i respectively. Whenever a crane does not have active connection with a control unit, it listens in on a channel 1107A which is common to the work site. Whenever a crane, in this 5 instance the crane 1102A, is assigned to a crane operator, in this instance 1106A, a central radio unit 1108A seeks contact with the assigned crane 1102A, which is identified by 2i, and informs the crane operator 1106A of the identity of the monitoring/control unit, 6i or 10 alternatively the network key based on 6i. Once the crane operator is on the spot, he starts up his monitoring/control unit. The crane unit seeks contact on the general channel with the selected monitoring/control unit 1006A having the identity 6i and when they have made 15 contact with each other the crane reports its identity 2i and the fact that it is master of the connection. A connection is then set up on an exclusive channel 1109A, i.e. the crane communicates how frequency jumping is to be done. In brief, it is therefore the case that cranes 20 which do not have contact with a selected control unit, in terms of radiocommunication, comply with the jumping frequency from a central unit. Once contact is obtained with a selected monitoring/control unit, the crane establishes contact with this, leaves the central unit 25 and assumes control over the generation of frequency jumping. The monitoring/control unit complies with this. If the radio connection is of the "spread spectrum" type, then the dispersion code is given instead of the jump plan.

30 A plurality of control units can be assigned to one and the same crane. They then belong to the same network. In the working range of the crane, a particular monitoring/control unit is assigned to a part-region. The part-regions can be partially overlapping or the crane 35 can follow a predetermined path between the part-regions. The crane is thereby able to be reliably controlled at a number of sites. When the load enters into a part-region, it obeys only that control unit which is responsible for the area. There are a number of ways of solving the

allocation of who has control over the machine on a given occasion. A further alternative is that the machine, after a certain period in which no control command is forthcoming, for example two seconds, accepts that
5 particular transmitter, of those which are accepted, which first issues the control command. The machine then obeys this transmitter until such time as it has failed to give any control commands for a two second period.

In systems, especially those which are constructed according to the principles contained in CAN Kingdom, in which a plurality of remote control units are able to operate one and the same unit, control commands from a particular remote control are assigned to a CAN-
10 Identifier by the system node of the controlled unit. The control commands are in this case first received by the system node, which, in turn, transmits control messages on the CAN-bus of the machine. The system node can receive control commands from all remote control units which communicate on the network key common to the
15 machine and can then select which remote control unit's control commands will be implemented according to a set of rules, for example the work area within which the unit is situated or, quite simply, that the remote control unit which first gives a shift command then retains
20 control until it issues a code for relinquishment of the control, is shut off or remains inactive for a predetermined period. Thereafter, the system node of the machine waits for a first best command from any of the authorised
25 remote control units and then executes control commands only from this latter until the particular remote control unit hands over control according to the above.
30

In a number of machines, for example process machines, a large number of measuring points and adjusting appliances are apparent, which are geographically dispersed and on many occasions poorly accessible. The operator sits in a room in which he supervises and controls the entire system via VDU's. Whenever something is detected which calls for on-the-spot observation, a communication problem arises. For example, a closed

position of a valve is indicated, which should be open. When the operator makes an on-the-spot visual inspection, he sees that the valve is open. Has it opened whilst he was on his way to the valve or is the valve signalling a closed position despite the fact that it is open? If now a WCMNM-module [sic] is connected and he has a MMI as previously described, then he can read on the spot the message which the valve is transmitting on the CAN-bus and decide whether there is a fault with the valve or not. The WCANM-module connected to the CAN-bus, from the viewpoint of the CAN-signal, can be in a totally passive mode, i.e. not transmitting a single bit, not even an acknowledgement bit. It can also have a CAN-active mode, so that the operator from his MMI is able to command the valve to open or close so as to monitor its functioning there on the spot. Of course, the control system for the process plant would have to be made such that the operator's actions do not jeopardise the security of the process.

Figure 12 illustrates a machine-control and/or process-control system with its modules 1A, 2A, 3A and 4A, which are intercommunicable via a serial digital connection 5A in a manner which is known per se. In order to simplify representation, the designation "CAN-system" is applied to this system. According to the invention, the module serves aggregates forming part of the said machine-control system and/or process-control system. In Figure 12 a valve in the aggregate is indicated by 6A and a thermometer in the aggregate by 7A. The length L of the connection 5A can be relatively long and can stretch over 200 m, for example. The modules and aggregates in the system can also be situated out of sight of each other.

In systems of this category, there is a need to be able to initiate a fault-searching, testing, control operation, etc. at the first module 1A. Such fault-searching or equivalent can require that second modules in the system need to be stimulated or need to establish signal transmissions or signal receptions at certain

stages of the fault-search or equivalent. In order to save staff, a radiocommunication apparatus is used, comprising two radiocommunication equipment parts 8A and 9A. The first part 8A can be independent from the CAN-system, whilst the communication part 9A is connected to or forms part of the second module. The connection between the part 9A and the module 4A can herein be made via a connection 10A, which can consist of a physical connection, non-galvanic connection, wireless connection, etc. The module 4A can be temporarily or permanently connected to the CAN-bus. The radiocommunication equipment 8A, 9A operates, where appropriate, with two-way connections 11A, 12A. The communication equipment 8A, 9A can in this case utilise one or more channels, with use preferably being made of radio channels in the broad-band range, i.e. in the range of frequencies above 1 GHz, for example the ISM-band. The radiocommunication equipment part 8A is provided with a control panel 13A, which can be of a type which is known per se. The panel is connected to the transmitting and receiving unit 14A of the part 8A, which incidentally can be of identical type to 9A, via an adjusting unit 15A. As a supplement thereto, the panel can be directly connected to the aggregate or components served by the first module 1A. This connection is effected via a second adjustment unit 16A and the connection per se is symbolised by 17A.

An initiation i1 at the panel 13A induces an activation of the transmitting part 14A, which, via a channel 11A, transmits the activation to the radio receiver part 9A. This receipt gives rise to a signal generation i2 to the module 4A via an adjustment unit 23A. The module contains a microprocessor 18A, which causes a signal message 19A to be generated, which is then transmitted to the connection 5A via the communication circuit 20A of the module 4A (see Figure 1). The transmission can be made according to an order of priority which is determined by the CAN-protocol and in which the module, after admission to the connection 5A, is able to transmit the message in question to the first module.

Once the message 19A is received in the first module, a functional stimulation of the component 6A, 7A or the equipment in question is realised, which functional stimulation is provoked by the initiation i1 at the control panel. The control operation can in this case comprise a reversal of the valve 6A, a raising or lowering of the temperature 7A, etc. The said reversal or temperature change can be visible to an observer at the first module. Through stimulations of his control unit 13A, the observer is therefore able to obtain visual evidence of whether the control system in question is accomplishing what it is meant to. At the control unit 13A, information 13A can also be obtained from the components or aggregate served by the module 1A. By keeping the radiocommunication equipment connected, registration and viewing can be carried out for shorter or longer periods of time.

Alternatively, a manual, electrical or other stimulation of the components or of the aggregate served by the first module 1A can initiate a message 21A generated in the first module, which message is transmitted to the second module 4A via the communication circuit 22A in the first module and the connection 5A. The said signal message 21A induces a signal initiation i4 in the second module and activation of the transmitter part in the radiocommunication equipment part 9A. Via a channel 12A, the information in question is transmitted to the receiving part in the radiocommunication part 14A and thereupon gives rise to the generation of an information signal i5 to the adjustment unit 15A, for onward conveyance to the control unit 13A or an information-supplying unit at which the information is displayed or registered. A location or site for the first module 1A is indicated by A, whilst a corresponding location or site for the module 4A is indicated by B. After the operator has carried out a check or fault-search at module 1A, he can proceed to module 3A, for example, and carry out equivalent work, providing that the module 4A is kept connected. He does not in this case need to connect any equipment to the

CAN-bus, but can continue to use the radiocommunication equipment 9A to transmit suitable messages and receive chosen messages on the CAN-bus, via the still connected units 4A and 9A. For communication over very long distances, up to a few kilometres, it may be necessary to have directional receiving antennae in order to satisfy standards relating to maximum transmitted power. Figure 13 shows such an arrangement for radiocommunication units of previously described type, 24A and 25A, which are each equipped with an omnidirectional transmitter antenna 24aA and 25aA respectively and a directional antenna 24bA and 25bA respectively. Other equipment in Figure 1 is symbolised by 4A' and 8A'.

Figure 14 shows a diagrammatic representation of a monitoring/control unit 201A (cf. 4 in Figure 1), having one or more CPU's 202A, memories 203A, a CPU-integrated or free-standing CAN-Controller 204A, a CAN-driver 205A, communication adjustment circuits 206A, etc. The unit 201A is built for the CAN-protocol and is connectable firstly to a radio unit 208A and secondly to a CAN-connection 207A. The radio unit 208A comprises two diagrammatically illustrated communication parts, a radiocommunication part 209A having first hardware and software, which enables a wireless communication to be set up between different radio units, and a second part having hard and software, incorporating one or more CPU's 210A, memories 211A, communication adjustment circuits 212A, etc., which allows communication with the unit 201A. Examples of such radio units are WaveRider from GEC Plessey (GB) and examples of a CAN-unit are CANnonBall and mini-CB from KVASER AB (SE). The present invention can be implemented using these standard units. The radio part 208A and the CAN-part 201A have at least one CPU each and can intercommunicate via a serial or parallel interface 213A. The parts 201A and 208A can be built together in a common casing or, as in Figure 5, can be applied each in its own casing 214A and 215A, and can be mutually connected by a connector 216A. An advantage of having the radio unit 208A and the CAN-unit 201A mounted

each in its own casing is that the radio unit can be easily exchanged in the event of fault and replaced by a similar radio unit in order to satisfy national or regional radiocommunication regulations. The CAN-part can 5 in this case be a standard unit with a parallel or serial output which allows connection to a unit equivalent to 208A. If WaveRider is chosen as the radio part, the interface 213A will consist of eight lines for data, a so-called "data bus", six lines for handshaking (three in 10 each direction) and one line for a feedback signal for initiating the radio when the system is started up. Each radio part has a unique identity, in the case of WaveRider an Ethernet address, and each CAN-unit has a unique 15 identity, for example an EAN-number including a serial number. Each unit which will be able to be controlled also has a unique identity, for example an EAN-number including a serial number.

Data transfer of an eight-bit byte from the CPU 202A to the CPU 210A is effected such that 202A activates 20 an interruption signal to 210A, which responds with an acknowledgement signal indicating that it is ready to receive data. (Otherwise a signal is activated which signifies "try again once more"). 202A presents a byte on the data bus and activates the signal "data are accessible". 210A reads the byte, acknowledges the transfer and stores it away in the memory 211A. This is repeated until 25 all of the byte is transferred. Transfer from 210A to 202A is carried out in reverse.

Figure 15 describes a detailed illustrative 30 embodiment of signalling from a module corresponding to the panel 13A according to Figure 1, generation of a message and the shaping of the message and its insertion on the bus and reception [lacuna] a module corresponding to 1A. Figure 15 shows only an operator unit 301A connected to a communication unit 302A via a CAN-interface 303A and a communication unit 304A and a valve with control electronics 305A connected to a CAN-bus 306A. Other modules connected to 306A are not depicted, but the 35 total system corresponds to that shown in Figure 1. Both

the units 302A and 304A each constitute a complete radio unit corresponding to the whole of the device in Figure 2, i.e. the radio unit can send and receive a message both via a CAN-bus and via the ether. A modulation command to the valve 305A (cf. 6 in Figure 1) is generated from the operator unit 301A and is transferred as a CAN-message 307A to the CAN-Controller of the communication unit, which forwards the data 308A to the CPU in the CAN-part. This creates a message 309A formatted for the radio part. 309A is described in detail by 310A, which has the following byte sequence: an overhead block with the parts 321A and 322A, in which 321A comprises two bytes 311A which indicate the number of bytes making up the message inclusive of 311A, a two-byte sequential number 312A (for suppression of subsequent multiply transmitted radio messages), and a six-byte long destination address 313A, a six-byte long consignor address 314A, two bytes 315A indicating the number of bytes of user data 316A to follow, and the part 322A made up of two or three bytes 317A which conclude the string. The user data 316A are the same as 308A. The CPU in the radio part takes charge of the arrived string and converts it into a radio message 318A with a necessary overhead 319A - for setting up and synchronising the radio transfer - and 320A for concluding the sequence and ensuring it was correct in terms of the CRC check total, etc. The radio overhead incorporates the information 321A and 322A. The radio module in the communication unit 304A receives the string 318A and recreates the string 310A, this being transferred to the CPU of the CAN-unit, which extracts 323A and creates the information for the CAN-Controller, which then, in turn, presents the CAN-message 324A on the CAN-connection 306A. The valve unit 305A now receives the command via the CAN-connection and implements the same, which can be verified by the operator.

The invention is not limited to the embodiment shown by way of example above, but can be subject to modifications within the framework of the subsequent patent claims and the inventive concept.